The need for a comprehensive and consistent approach in sustainability assessment of buildings - the EC Product Environmental Footprint

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Short Summary

To date a proliferation of sustainability claims in architecture is noticed. The major focus is on energy and related CO_2 and on the use stage of buildings. Although energy during the building use stage is highly relevant, a more comprehensive life cycle approach is needed to support decision making in order not to overlook relevant environmental burdens such as respiratory effects and land use. This proliferation of sustainability claims is not only noticed in the building sector. Also in other sectors confusion in the market on how to measure the environmental performance has appeared due to this proliferation of claims. This can lead to unfair commercial practices and greenwashing. As a base for addressing the current confusion in the market, the Environmental Footprint was developed and has recently been adopted by the European Commission. This method provides specific guidance for comprehensive, robust and consistent environmental assessment of products and organisations. It is based on four main principles: (1) multi-criteria, (2) life cycle thinking, (3) consistency and (4) ensuring maximally physically representative modeling. This paper presents the Product Environmental Footprint in the specific context of buildings.

Keywords: Labelling, Life Cycle Assessment, Multi-criteria approach, Product Environmental Footprint, Sustainable Buildings.

1. Introduction

Although the construction sector contributes to socioeconomic development, it also induces important environmental impacts due to its energy consumption, solid waste generation, global greenhouse gas emissions, adverse health effects, environmental damage, resource depletion and land use [1], [2]. It is therefore a relevant sector in terms of reducing the environmental impact. Sustainability and environmental impact of buildings have hence received a high interest in the last decades. In this context, a proliferation of sustainability claims of buildings is noticed to date, such as ‘Passive House’, ‘Ecological Passive House’, ‘Net Zero Energy Building’, ‘CO_2 neutral building’, ‘Solar Self Sufficient Building’, ‘Autonomous object’, ‘Energy Autonomous City’, ‘Mixed-use Carbon Neutral development’, ‘Eco-village’, ‘2000 Watt City’ and many more [3], [4], [5], [6], [7], [8]. The major focus is clearly on energy and related CO_2 and on the use stage of buildings. By limiting the focus to a single environmental impact category and/or a single life cycle stage there is however a potential risk of burden shifting to other impact categories and/or other life cycle stages [1], [9].

In a response to that, more holistic evaluation methods (and related labels) have appeared such as the Leadership in Energy and Environmental Design (LEED) rating system ([10], [11]), the BRE

Environmental Assessment Method (BREEAM) ([12], [13]) and the German Sustainable Building Council (DGNB) [14] system. These are more holistic as these include other life cycle stages than the use stage and consider other impacts in addition to global warming (multi-criteria). As the different systems lead to different recommendations and labels [15], the confusion in the market however remains. Moreover, although these holistic evaluation methods are more comprehensive, they show some important drawbacks. This is elaborated in section 2 of this paper. To overcome the drawbacks a detailed and rather prescriptive Life Cycle Assessment (LCA) method is recommended and has been adopted by the European Commission (EC), the Product Environmental Footprint (PEF) [17]. This method is presented in section 3. The scope of the PEF method is however not limited to the construction sector. More specific PEF category rules for construction products and buildings are needed to define even more clear, relevant and actionable guidelines in order to guarantee consistency and comparability of PEF studies. Another European initiative is the development of the standards of the CEN TC350 which provide such more specific guidelines (Product Category Rules). The two most relevant ones in the context of this paper are the EN15804 [18] and EN15978 [19]. The development of future PEFCRs for construction products and the harmonization with the CEN TC350 standards are further discussed in section 4. Some conclusions and steps forward are summarized in the final section.

2. Existing comprehensive assessment methods for buildings

This section provides an overview of three widely used comprehensive sustainability assessment methods for buildings, i.e. LEED, BREEAM and DGNB system. The methods are here briefly presented in order to illustrate their scope and importance. We refer to literature for a more comprehensive description and analysis, including implementation to case studies [20], [21], [22], [23], [24]. Some issues for improvements and the related recommendation for a multi-criteria LCA based approach are moreover discussed. The description mainly focuses on the environmental issues, as this serves as background for the subsequent section which presents the EC PEF method and indicates how the EC PEF method can contribute to an improvement of the environmental impact assessment of the existing methods.

2.1 Overview of existing methods

2.1.1 Building Research Establishment Environmental Assessment Method (BREEAM)

BREEAM was developed in 1990 and as such is the oldest certification system for sustainable building. It has become one of the most widely recognised systems with more than 250.000 buildings certified [12]. It assesses the environmental performance of buildings and includes aspects related to energy, water use, the internal environment (health and well-being), pollution, transport, materials, waste, ecology and management processes.

BREEAM considers nine categories (*Table 1a*). There are a number of aspects that determine the BREEAM rating: rating benchmarks (*Table 1b*), environmental weightings (*Table 1a*), minimum standards (i.e. minimum number of credits achieved within the sub-criteria of the nine categories), credits achieved and additional credits achieved for innovation (maximum 10 additional credits, which equals a maximum of 10% to be added to the rating score) [25]. The certification levels range from pass to outstanding.

Life cycle environmental impact assessment is mainly addressed in the category ‘materials’ by providing a link with the *Green Guide to Specification* ratings [26]. This *Green Guide to Specification* provides environmental rankings (i.e. from A+ to E) of materials and components for different building elements used in different buildings. It is based on LCA using BRE's Environmental Profiles Methodology 2007 [27]. This methodology comprises 13 environmental impact categories, including amongst others climate change, human toxicity, water extraction, fossil fuel depletion and acidification. The characterisation factors are mainly taken from the CML 2000 method combined with characterisation factors developed by BRE for any gaps [27]. For the total BREEAM rating, maximum six credits can be obtained by following the Green Guide to Specification within the category ‘Materials’. As in total 12 credits can be obtained in this Category and the weight of this category is 12.5%, only 6.25% of the total BREEAM rating score is based on LCA of the building materials used.

Table 1: BREEAM$_{2008}$: weighting scheme for new builds, extensions and major refurbishments (table 1a) and certification level (table 1b), ([25], page 3).

Table 1a

Category	BREEAM$_{2008}$
Management	12%
Health and wellbeing	15%
Energy	19%
Transport	8%
Water	6%
Materials	12.5%
Waste	7.5%
Land use and ecology	10%
Pollution	10%

Table 1b

BREEAM$_{2008}$ rating	% score
Unclassified	<30
Pass	≥30
Good	≥45
Very good	≥55
Excellent	≥70
Outstanding*	≥85

*Additional requirements for achieving a BREEAM Outstanding rating.

2.1.2 Leadership in Energy and Environmental Design (LEED)

LEED is developed in 1998 by the U.S. Green Building Council. LEED is a voluntary, consensus based national rating system for buildings designed, constructed and operated for improved environmental and human health performance. It evaluates the environmental performance of a building over its entire life cycle. In 2013 over 10.000 buildings have been certified [11].

A project must satisfy all LEED prerequisites and earn a minimum number of points on a LEED rating system scale. Homes for example must earn a minimum of 45 points on a 136-point scale (*Table 2b*). The certification levels range from certified to platinum. The points to be gained are subdivided in eight categories (*Table 2a*). These consist of a number of measures which are prerequisites and/or a number of measures resulting in credits of one or more points. As the number of measures differs between the different categories and the number of points for the measures differs, weighting factors are implicitly assigned (*Table 2a*). It is however not clear how the measures within each category were selected and how the number of points was assigned to each measure.

Table 2: LEED for Homes (v. 2008): Weighting scheme (Table 2a, [11]) and certification level (Table 2b, [10]).

Table 2a

Category	LEED$_{2008}$
Innovation and Design Process	8%
Location and Linkages	7%
Sustainable Sites	16%
Water efficiency	11%
Energy and Atmosphere	28%
Materials and Resources	12%
Indoor Environmental Quality	15%
Awareness and Education	2%

Table 2b

LEED$_{2008}$ certification levels	Number of points required
Certified	45-59
Silver	60-74
Gold	75-89
Platinum	90-136
Total Available points	136

2.1.3 German Sustainable Building Council (DGNB) system

In 2009 the DGNB introduced a new system that can be seen as a second-generation scheme as it built on the experiences of the existing schemes at that time such as BREEAM and LEED. In 2012 over 200 buildings have been certified in Germany and abroad [22]. It is more holistic than the previously discussed systems as it is not limited to environmental and health issues.

The DGNB system gives equal weight (22.5%) to the widely accepted three pillars of sustainability: environmental, economic and social pillars. It moreover considers the technical quality (22.5%), the process quality (10%) and the location quality (0%, which actually means it is not considered). The total score of the building is calculated based on the weighted individual scores on each criterion (about 50 in total). Based on this total score, a bronze, silver or gold certificate can be obtained (*Table 3b*). The gold certificate is reached when 80% of the possible maximum score is reached. As described by Schuster et al. "*this can only be achieved with a performance far better than required by law, e.g. with extremely high energy performance and/or low emission material selection"* [22].

In *Table 3a,* the indicators in the environmental pillar are summarised together with their weighting factors (in relation to the overall DGNB score). The environmental impact assessment is based on the CML 2001 characterization model and represents 13.5% of the total DGNB score [28].

Table 3: DGNB system: weighting scheme for ecological quality issues of overall certification (Table 3a) and certification level (Table 3b) [20].

Table 3a

Indicator	**Weight**
Global Warming Potential (GWP, kg CO_2 eq.)*	3.46%
Ozone Depletion Potential (ODP, kg CFC_{11} eq.)*	0.58%
Photochemical Ozone Creation Potential (POCP, kg C_2H_4 eq.))*	0.58%
Acidification Potential (AP, kg SO_2 eq.)*	1.15%
Eutrophication Potential (EP, kg PO_4 eq.)*	1.15%
Risks to the regional environment	3.46%
Other impacts on the global environment	1.15%
Microclimate	0.58%
Non-renewable primary energy demand* (MJ)	3.46%
Total primary energy demand and proportion of renewable primary energy* (MJ)	2.31%
Potable water demand and sewage generation	2.31%
Land use	2.31%

* Based on LCA.

Table 3b

Total Performance Index	**Awards**
From 50%	Bronze
From 65%	Silver
From 80%	Gold

2.2 Need for improvement

Although assessment methods such as LEED, BREEAM and the DGNB system have clearly their strengths in terms of comprehensiveness and awareness raising, they also show some weaknesses. The most important need for improvement is the consistency and rigidness of the methods for the determination of the environmental benefits assigned to each building measure and the relative importance of each of the measures. Based on an LCA of the measures in the LEED method, Humbert et al. concluded that actually not all measures are environmentally beneficial but some result in an environmental burden instead [29]. This was for example the case for the measure '*provide alternative fuel vehicles or install alternative refuelling stations for 3% vehicle parking capacity*' within the category '*sustainable sites*'. This measure was translated into "*3% of the cars driven with bioethanol instead of gasoline*" by Humbert et al. and proved to lead to a positive impact on depletion of resources but to a damage to human health and ecosystems based on their LCA study [29]. Similar critics can be formulated for the BREEAM method as it was identified that it does not use an LCA approach consistently throughout the assessment. The environmental assessment of the DGNB method only comprises a limited number of impact categories and the impact assessment models used date from 2001. It therefore shows room for improvement.

A comprehensive LCA of the environmental impacts is hence recommended to improve the existing methods. Consistency over the different building types, but also over the different EU

Member States would be beneficial in terms of transparency and comparability. It would moreover be advantageous for the assessors to have a consistent method in different building locations in terms of time and money. The EC PEF method exactly aims at providing consistent, LCA based, clear and actionable guidance and is further elaborated in the subsequent section. Besides the EC PEF method, the CEN TC350 developed LCA standards for construction products and buildings, i.e. the EN15804 and EN15978 standards respectively [18], [19]. These are further discussed in the subsequent section related to more specific PEF category rules for the construction products.

3. The EC Product Environmental Footprint (PEF)

3.1 Background

The EC PEF method has been developed by the Joint Research Centre (JRC) of the EC in close cooperation with the Directorate General for the Environment (DG ENV). It was recently published as an annex of the recommendation linked to the Communication "*Building the Single Market for Green Products - Facilitating better information on the environmental performance of products and organisations*" [16], [17], [30]. The aim of the PEF is to bring comparable and reliable environmental information in order to build confidence for consumers, business partners, investors and other stakeholders. It should provide the basis for addressing the current confusion of sustainability claims which is not only noticed in the building sector.

The EC PEF method is an LCA based method to calculate the environmental performance of a product (i.e. good or service). PEF information is produced for the overarching purpose of seeking to reduce the environmental impacts of products taking into account supply chain activities (from extraction of raw materials, through production and use, to final waste management). The EC PEF method provides guidance for modelling the environmental impact of the flows of material, energy and the emissions and waste streams associated with a product throughout its life cycle. It builds upon the ISO 14040 and ISO 14044 standards [31], [32] and the International Reference Life Cycle Data System (ILCD) Handbook [33]. The EC PEF method is however more prescriptive than any of these documents in order to increase consistency and reproducibility. The relation with the ISO standards and the ILCD handbook are schematically presented in *Fig. 1*. Besides these reference documents, existing footprinting methods were consulted at the start of the development process of the EC PEF method such as PAS 2050 [34], Greenhouse Gas Protocol [35], [36] and BPX 30-323-0 [37]. Briefly summarised it can be concluded that existing methods are not prescriptive enough (to guarantee consistent and comparable outcomes) and not comprehensive enough (i.e. limited to a single issue instead of multi-criteria) to fulfil the goals set for the EC PEF method. A detailed description of the analysis of existing footprinting methods can be found in [38].

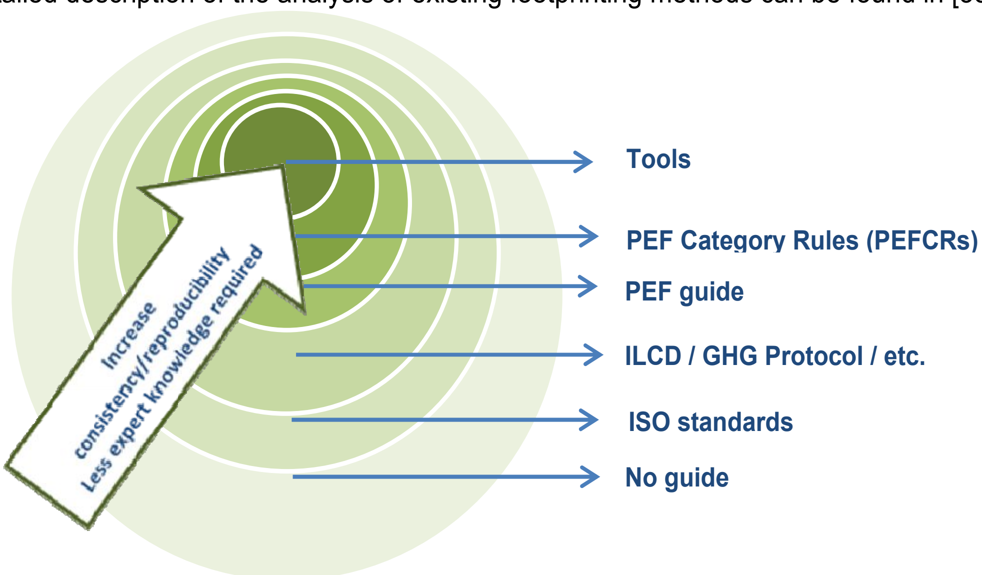

Fig. 1 Situating standards and methods for product environmental footprinting along the continuum from flexibility to prescriptiveness/reproducibility

3.2 Scope

The EC PEF method can be applied to all products including construction products. The system boundary includes all life cycle stages from raw material extraction through processing, production, distribution, storage, use and End-of-Life (EoL) treatment of the product (i.e. cradle-to-grave), as appropriate to the intended application of the study. As the EC PEF method has a wider scope than only building products, additional, even more specific, requirements for the building sector will be necessary to increase reproducibility, consistency and relevance of PEF studies of construction products. These additional guidelines are referred to as Product Environmental Footprint Category Rules (PEFCRs) and are further discussed in section 4.

3.3 Prescriptiveness

The EC PEF Guide has a high level of prescriptiveness and hence a low level of flexibility. This was seen as essential in order to obtain more consistent and comparable results. The EC PEF Guide provides for example strict guidelines regarding the data quality, allocation, EoL allocation, cut-off, impact assessment, biogenic carbon removals and emissions, temporary carbon storage and nomenclature. This is in contrast with many other currently available methods which in general allow the user to choose out of a range of possibilities. The data quality requirements and environmental impact assessment are described in more detail in the subsequent sections as these are important issues for all environmental assessments, including buildings.

3.4 Data quality requirements

Strict data quality requirements are included in the EC PEF Guide in order to ensure good quality results. A semi-quantitative assessment is required addressing six criteria: technological representativeness, geographical representativeness, time-related representativeness, completeness, parameter uncertainty and methodological appropriateness and consistency. The single scores are combined giving equal weight to each criterion in order to obtain the overall data quality rating. The overall rating ranges from poor to excellent. For the processes accounting for at least 70% of contributions to each impact category, data shall achieve at least an overall “good quality” level, for at least 20% of the remaining impact “fair quality” data shall be used, and for the remaining processes (maximum 10% of the impact) at least best available data shall be used (*Fig. 2*). The European reference Life Cycle Database (ELCD) and the International Reference Life Cycle Data System Data Network (ILCD DN) will play a crucial role in achieving this fundamental goal of coherent and quality assured data [39].

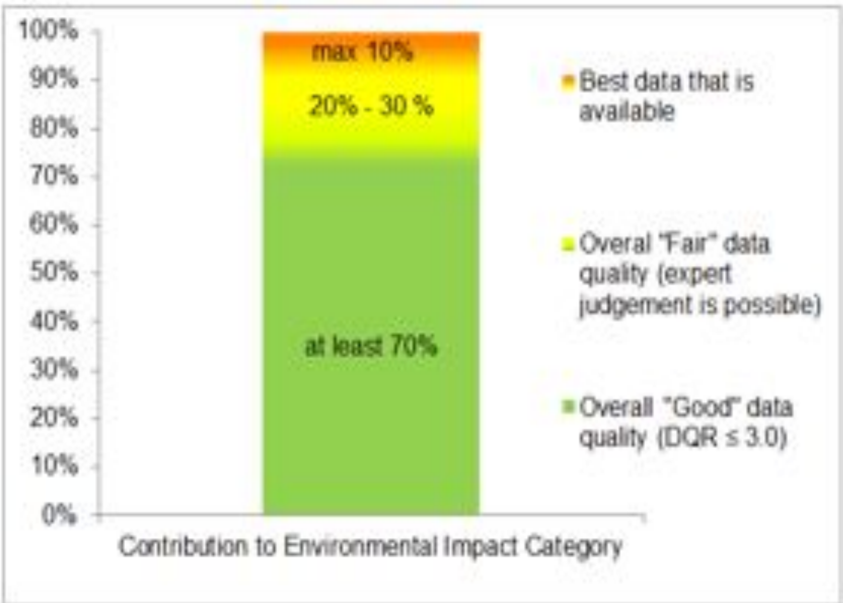

Fig. 2 Data quality requirements according to the PEF Guide.

3.5 Environmental impact assessment

The EC PEF method includes a comprehensive list of 14 impact categories and prescribes the midpoint models, related indicators and characterisation factors to be used (*Table 4*). This is based on the ILCD recommendations [33] agreed upon internationally and is therefore widely supported.

Table 4: Product Environmental Footprint: impact categories, assessment models and indicators.

Impact Category	Assessment Model	Indicators
Climate Change	Bern model - Global Warming Potential over a 100 year time horizon.	kg CO_2 eq.
Ozone Depletion	EDIP model based on the ODPs of the World Meteorological Organization (WMO) over an infinite time horizon.	kg CFC-11 eq.*
Ecotoxicity for aquatic fresh water	USEtox model	CTUe **
Human Toxicity - cancer effects	USEtox model	CTUh ***
Human Toxicity – non-cancer effects	USEtox model	CTUh ***
Particulate Matter/Respiratory Inorganics	RiskPoll model	kg PM2.5 eq. ****
Ionising Radiation – human health effects	Human Health effect model	kg U^{235} eq. (to air)
Photochemical Ozone Formation	LOTOS-EUROS model	kg NMVOC eq. *****
Acidification	Accumulated Exceedance model	mol H+ eq
Eutrophication – terrestrial	Accumulated Exceedance model	mol N eq
Eutrophication – aquatic	EUTREND model	fresh water: kg P eq. marine: kg N eq.
Resource Depletion – water	Swiss Ecoscarcity model	m^3 water use related to local scarcity of water
Resource Depletion – mineral, fossil	CML2002 model	kg Sb eq. ******
Land Use	Soil Organic Matter (SOM) model	kg (deficit)
* CFC-11 = Trichlorofluoromethane, also called freon-11 or R-11, is a chlorofluorocarbon. ** CTUe = Comparative Toxic Unit for ecosystems *** CTUh = Comparative Toxic Unit for humans **** PM2.5 = Particulate Matter with a diameter of 2.5 µm or less. ***** NMVOC = Non-Methane Volatile Organic Compounds ****** Sb = Antimony		

4. Product Environmental Footprint Category Rules (PEFCRs)

As mentioned in section 3.2, PEFCRs for the construction products will need to be developed in future in order to further increase consistency, reproducibility and relevance for the construction sector and to enable comparisons and comparative assertions. The PEFCRs should moreover reduce the time and efforts needed to conduct a PEF study by limiting the scope in terms of relevant processes/life cycle stages and impact assessment categories. Coherence of PEFCRs will be ensured trough the foreseen sectorial level guidance for their development. Existing product category rules (PCRs) for construction products should be consulted when creating the PEFCRs for construction products and buildings, especially the widely used EN15804 and EN15978 should be carefully considered. In addition, other existing PCRs of construction products should be taken into account as well, such as the BREEAM PCR [27]. Their requirements and assumptions regarding for example the reference service life of buildings and components, the technological, geographical and time-related representativeness of processes should be carefully considered.

5. Conclusions and steps forward

The current proliferation of methods for assessing the sustainability of buildings leads to inconsistency and hence confusion. Although comprehensive methods exist taking into account several sustainability issues and life cycle stages, the methods to date are mainly rating-based methods, also referred to as qualitative systems. They consist of a subjective weighting of credits assigned to a list of measures, covering different issues such as energy use, material choice and water efficiency. The need for a more consistent and comprehensive Life Cycle Assessment (LCA) based (quantitative) method is highlighted. The presented Product Environmental Footprint (PEF) method, recently adopted by the European Commission, gives an answer in terms of environmental impact assessment to the needs identified. The next step forward consists of developing Product Environmental Footprint Category Rules (PEFCRs) for construction products in order to increase consistency, reproducibility, relevance and comparability of building and building product assessments. In order to move towards a harmonised European method for construction products and buildings it will be important to envisage an alignment between the PEFCRs for construction products and the CEN standard EN15804.

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